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Fisheries and Prestige. Review and update of studies on the effects of the Prestige oil spill

by

Punzón[1], A., Trujillo[2], V., Abad[1], E., Pampillón[2], C., Velasco[1], F., Abaunza[1], P., F., Villamor[1], B., Perez[2], N. and Hernández[1], C

[1] Instittuto Español de Oceanografía, P.O. BOX 240, 39080 Santander, Spain. antonio.punzon@st.ieo.es; esther.abad@st.ieo.es; francisco.velasco@st.ieo.es; pablo.abaunza@st.ieo.es; begona.villamor@st.ieo.es; carmen.hernandez@st.ieo.es.

[2] Instittuto Español de Oceanografía, P.O. BOX 1552, 36280 Vigo, Spain: valentin.trujillo@vi.ieo.es ; jose.castro@vi.ieo.es; nelida.perez@vi.ieo.es

1 Abstract

The Prestige oil tanker sank in November 2002 and leaked around 60 000 mt. of heavy oil (type M-100) into the sea. Immediately after the accident, closed areas were established. Among the fleets affected by the closures were four of the most important in ICES Division VIIIc and Sub-division IXa North (bottom trawl, pair trawl, purse seine targeting sardine and hand line targeting mackerel) as they exploit considerable resources, some outside biological safety limits. A fall in effort was observed in all of them, mainly in the first quarter and in sub-divisions VIIIc West and IXa North, although it failed to lead to a very large reduction in the total annual effort of each of the fleets, with the exception of hand line. Pair trawlers can make two types of fishing trip, but differences in specific composition among the three years analysed were not found in either of them. In the case of trawl, five kinds of fishing trips were identified, and changes were only found in the type that targets Norway lobster, hake, megrim and monk (HMMN), with a fall in the presence of Norway lobster.

2 Introduction

The Prestige accident took place on the 13th of November 2002 and the vessel sank 6 days later, leaving a spill totalling approximately 60 000 mt of heavy oil (type M-100) in the sea. The oil spread along the entire length of the coast and continental shelf of Galicia and the Cantabrian Sea (Garcia-Soto, 2004, Punzón and Serrano 2003 and Sanchez, 2003), the distribution area of many of the fish and shellfish stocks exploited commercially in the Northeast Atlantic (figure 1). A large part of the exploited stocks of this area are currently outside biological safety limits.

Oil spills can affect fisheries resources in many different ways: 1) direct effects on populations (lethal or sub-lethal), 2) direct effects on fisheries or interference with fishing activity and 3) indirect effects through perturbations in the ecosystem (e.g. impacts on trophic chains) (Dipper and Chua, 1997 and Elliot et al., 2003). In addition to these, there is another set of possible indirect implications as a consequence of the management measures imposed following the spill, such as closed areas and limited access to traditional fishing grounds imposed for certain gears (Dipper and Chua, 1997), subsidies for the prohibition of the activity, compensation payments or participation in the cleaning-up work (Moller, et al., 1999, Surís and Garza, 2003) or modifications to the price of commercialization, e.g. the bio-economic model may be altered (Crean and Lacambra, 2003) in such a way that effort and the way it is exerted are affected. Management measures that have mainly been applied as a consequence of the impact that the presence of oil in fishing areas has on the workability of the gears, commercialization of species, suitability for human consumption, etc.

The establishment of closed areas usually follows a scientific study to determine the location, size and form as well as the duration based on ecological (abiotic and biological) and research and monitoring criteria (Sumaila, 1998), but this does not happen in cases of closures imposed following spills. Closed areas have potential benefits (Moller et al., 1999), although due to their temporary nature they may not have had an influence on all of them, particularly when it is known that the benefits to fisheries reserves take several decades to reach their potential maximum (Sobel and Dahlgren, 2004, Lindeboom, 1994). On the other hand, they may have led to important changes both in the way effort is exerted (Pastoors *et al*., 2000, Rijnsdorp *et al*., 2001) and in the pattern of exploitation. This study analyses some of the possible consequences of these closures both in quantity and in the way effort is exerted by the main industrial fleets working in the area.

3 Material and Methods

Management of the Prestige spill in relation to fisheries

The management of fishing activity in relation to the Prestige oil spill was carried out by the Administration, which established fishing limitations in certain areas and for certain gears. All legislation passed in relation to the Prestige spill and fishing activity has been compiled for this work.

Effort Time Series

For demersal fisheries two units were used depending on the gear in question, for bottom trawl fleets, fishing days per 100 HP and for pair trawl fleets the number of fishing trips. In both cases total monthly effort exerted was estimated for the whole area in which closed areas were imposed and also effort exerted by the most important fleets (figure 1 and table 1), in which fleet is understood as the combination of fishing gear, working area and landing port.

In the case of fisheries targeting pelagic species, the number of fishing days on which a specific species was landed per fishing gear was used. In this case it was impossible to estimate the total number of fishing trips targeting a species in the area affected by the spill, and so we selected the three most important fisheries in the area (table 1).

The historical series of monthly effort from 1996 to 2004 was compiled for all fleets, with the exception of the A Coruña trawl fleet in 1998 and Avilés in 2004, and of the purse seine fleet of Vigo in 2000 due to unavailability of data. In all cases the information came from Fishermen's Associations.

Spatial trawl effort

Information on spatial effort distribution came from observers on commercial boats of the Spanish trawl fleet operating in North Atlantic waters of the Iberian Peninsula (ICES Divisions VIIIc and IXa North). This sampling programme is funded throughout the Spanish National Sampling Scheme, adopted by the European Regulation EC-1639/2001. The onboard sampling programme is based on a stratified random sampling per Fishery Unit, which comprises area, gear and target species. Data collection is based on voluntary cooperation of vessels.

Data from years 2000 and 2003 were selected as representative of periods pre and post-spill. Year 2000 was particularly chosen because it presents the best sampling coverage of the last years. Haul locations were mapped by semester for both years.

Specific Composition Analysis by trawl trip

With the aim of identifying whether changes took place in the specific composition of the different types of trawl fishing trips made in the affected area (ICES Division VIIIc and Sub-division IXa North), fishing trips made in 2002 (pre-spill) and 2003 and 2004 (post-spill) were analysed for bottom trawl. A total of 12 906 fishing trips were sampled in 2002, 11 777 in 2003, and 8 285 in 2004. The database contained information of landed weight by boat and species for different strata on: fishing area (ICES Sub-division), type of gear, harbour and date. Weight landings were transformed into percentages and grouped in categories of species.

The original data frame was split by year for single bottom trawl and pair trawl to avoid the possible overlap of catch profiles. A non-hierarchical cluster analysis (K-mean method) (Hair *et al*., 1999) was performed for classifying the catch profiles. This method is especially useful when there is previous knowledge of the fishery (Kaufman and Rousseeuw, 1990).

Lengths

In order to identify possible changes in the strategies of exploitation of the main fleets working in the area, we used the proportion at length range and the relative proportion at length range of the Exploratory Data Analysis by length (Jardim and Azevedo, 2004):

$$P_{ys} = \frac{N_{ys}}{\sum N_{ys}} \qquad\qquad P^{r}{}_{ys} = \frac{P_{ys}}{\overline{P}_{s}}$$

where P_{ys} is the proportion at length range for the year and y the length range s, N_{ys} the number by length range, P^{r}_{ys} the relative proportion at length range and $\overline{P}_{s}$ is:

$$\overline{P}_{s} = \frac{\sum_{y}^{Y} P_{ys}}{Y}$$

4 Results

Closed areas

The first area closed to industrial fleets, in this case purse seine, was imposed by local authorities on the 18th of November, the day before the definitive sinking of the vessel. It was adopted by the national authorities on the 21st of the same month. For trawl fleets the first closure came on the 30th of November. The closures for this fleet exclusively were limited to the 12 mile strip outside interior waters. In the case of closures for pelagic fleets, the whole of the continental shelf and oceanic waters between two points marked on the coast were affected (figure).

The closed areas were progressively extended as the oil spread, and reached their maximum extension for both fisheries in February 2003 (figure 2). The closures were lifted for all fisheries at the end of June 2003. The longest had lasted 6 months.

Effort time series

A considerable fall was observed in the monthly effort exerted by the whole bottom trawl fleet between December 2002 and February 2003 (figure 3). January presented the lowest value of the whole historical series considered (1841 days by 100 HP). From March there was practically no difference from efforts exerted in previous years and in 2004. In the main bottom trawl fleets of ICES Sub-divisions VIIIc West (A Coruña) and IXa North (Marín and Vigo) the pattern of effort was similar, with a minimum in February and a recovery of effort to normal values from the second quarter (figure 4). Nevertheless, this behaviour was not observed in the Avilés fleet, the most important working in ICES Sub-division VIIIc East (figure 4), and the effort exerted specifically by this fleet during the spill was very similar to that of the previous year. The series trend in the total annual effort of this fleet is downwards (figure 3 and table 2)

The total effort of the pair trawl fleet during the spatial closures suffered a large fall from in 2002 and throughout the first half of 2003 (figure 5) The minimum effort in this period was reached in December and January. There was no clear trend in the last years and in 2003 the level was the same as in previous years (table 2). Indeed, total effort fell in 2004 with respect to the previous year. Regarding the series by most important ports, a fall in effort was seen in the same season as the general series in the Ribeira fleet, which mainly operates in IXa North, and the activity of the A Coruña fleet of Sub-division VIIIc West stopped in the first half of 2003 (figure 5). In the case of the Avilés fleet (Sub-division VIIIc East), no change on previous years was observed, and a fall only appeared during the summer, a pattern seen since 2001.

In both of the markedly seasonal fisheries targeting sardine, no important fall was observed in annual effort, although a stoppage in the activity in the first months of the year was found in the monthly analysis, coinciding to a great extent with the biological stoppage that was already in effect prior to the Prestige accident (figure 6). In the case of the hand line fishery targeting mackerel, a considerable fall in effort was observed throughout the fishing campaign of 2003.

Trawl effort spatial modification

Figure 7 shows the spatial distribution of trawl fishing effort for years 2000 (a) and 2003 (b). The overall effort pattern did not seem to change between the two years. Nevertheless, this must be treated with caution, since spatial movement within the semester could be hidden below the overall pattern.

Analysis of specific composition by trawl trip

The most reliable segmentation, taking into account the previous knowledge of the fishery, was obtained using seven clusters, five for single trawl and two for pair trawl. Increasing the number of clusters creates nonsensical groups and does not improve the robustness of the clusters. These results describe more components than in previous analyses (Punzón et al., 2001; Bellido et al., 2003).

The five clusters obtained in the single trawl data set show the catch profile and might be denominated as follows: trips targeting Horse Mackerel (HM); trips targeting Mackerel (M); trips targeting Hake-Megrim-Monk-Nephrops (HMMN); trips targeting Blue Whiting (BW); and “mixed” trips (MX) (figure 8). The catch profiles do not present great changes among the three years analysed. The largest changes can be observed in the components “HMMN” once more, in which a large drop was seen in the percentage of *Nephrops norvegicus* in 2003 and 2004,

The two clusters obtained from the pair trawl fleet show two profiles (figure 9), trips targeting blue whiting and trips targeting hake. When we compare both components between years, an identical catch profile is found in the component “blue whiting” while the component “hake” shows an increased percentage of hake in 2003 and 2004.

Length exploratory analyses

Although the exploratory analyses have been carried out of the exploitation strategies of the main fleets targeting the demersal species subject to monitoring by ICES assessment groups and of the main mackerel fishery in the Cantabrian Sea (table 3), and given that the results obtained regarding the analysis of the possible effects of the areas closed due to the Prestige spill were practically the same, we only present the most relevant species in the analysis of these results. There are no changes to the year in which the closed areas were in effect, nor in 2004 (figures 10, 11, 12 and 13)

5 Discussion

One of the immediate consequences of a spill such as that of the Prestige is the imposition of Areas Closed to Fishing as a measure to protect consumers (White and Baker, 1998 and Moller, et al., 1999). The most important impacts of an oil spill, or at least the most evident, usually appear in the inter-tidal strip near the areas of spillage (Lancaster et al. 1998) where most accidents occur. For this reason in most cases, as in the accidents of the Jessica in the Galapagos Islands (Born, et al., 2003) and the Sea Empress in Milford Haven Southwest of Wales (Law and Nelly, 2004) among others, the closures are restricted to the coastal area. In the case of the Prestige accident, and as a consequence of the spread of the oil both on the surface (Garcia-Soto, 2004, CEDRE, 2004) and on the bottom (Punzón and Serrano, 2003 and Sanchez et al.,2003), the closed areas affected a large part of the continental shelf, and therefore the fisheries of the area, both artisanal and industrial.

Pelagic fisheries

The size of the oil patches on the surface and the rapid changes in their distribution and trajectories according to meteorological and oceanographic conditions led to the imposition of closed areas affecting practically the entire continental shelf between January and March 2003 in order to protect both public health and vessels and their gears (Villamor, 2003).

Semi-industrial pelagic fisheries such as purse seine were seriously affected despite their great capacity for movement, since their exploitation criteria are very similar to those of the artisanal fisheries (fishing trips of less than 24 hours, resources with marked seasonality, usually distributed close to the coast, etc). These characteristics led to the diversity of the extent of the impact of the closed areas on the different pelagic fisheries depending on their seasonality. Thus, a small fall in effort was observed in the purse seine fishery targeting sardine at the beginning of the fishing season, but this was scarcely reflected in the annual effort exerted by the main fleets due to the fact that it coincided to a great extent with the existing biological stoppage. In the case of the hand line fishery targeting mackerel on the other hand, there was a large fall in effort, given that the closed areas directly affected the spawning season of this species (Punzón, 2004). This consequently led to a considerable reduction in catches (ICES, 2005) and partial fishing mortalities in 2003, although given historical variability it is very difficult to establish a direct relationship between this fall and the spill (Trujillo, et al., 2005). No change could be seen in the explotation strategy used by the hand line fleet targeting this species (figure 13)

Demersal fisheries

The closed areas imposed on these fisheries largely coincided with the distribution of oil on the bottom (Punzon and Serrano, 2003, Sánchez et al, 2003) and were limited to the coastal strip of the continental shelf. This situation, together with the fact that the fleet has a great capacity of movement, meant that, as in other spills (Born, et al., 2003), the efforts exerted by fleets of these or similar characteristics were not greatly affected, and only a fall in effort was seen in some fleets at the beginning of 2003

Another of the possible consequences of the imposition of closed areas, unrelated to a stoppage of the activity, may be associated with the displacements of the fleet (Gulland, 1974) and therefore a transfer of effort. With the information available we were unable to observe any changes in the distribution of effort in the continental shelf. This may be due to the fact that the closed areas arising from the management of the spill (figure 2) overlap to a great extent with the annual spatial closed areas imposed on trawl during this season (figure 14), mainly to protect hake recruitment.

The case of the pair trawl fleet was special in that one of the fleets (Ribeira) did present a reduction in effort, and in another a total absence of activity (A Coruña) during the first semester of 2003. This may be because it was off the coast of this port that the area closed to trawl lasted the longest (Figure 1and 5). Moreover, although the technical characteristics of the fleet that participates in this fishery are the same as those of bottom trawl (Punzón, et al., 2001), they mostly behave similarly to pelagic fisheries, with trips of less than 24 h and most operations close to the landing port. In the total annual effort of 2003, a fall was seen with respect to the previous year, although it was within the levels of previous years, and so the stoppage of the fleet of A Coruña did not appear to greatly affect the overall effort exerted by this fleet.

Even so, the effects of the closures were similar in both the bottom trawl and the pair trawl fleets, and led to a fall in effort intensity exclusively in ICES Sub-divisions VIIIc West and IXa North, while no effect was found in the Cantabrian Sea area (Sub-division VIIIc East). No changes were found in either case in the exploitation strategy for the main target species (figures 10, 11 and 12)

In the two identified types of fishing trip made by the pair trawlers, targeting hake and blue whiting respectively, differences were not observed among the three years analysed. In the case of trawl fishing trips, five types of fishing trip were identified and only in the component HMMN, whose main target species are hake, Norway lobster, megrim and monk, was a decrease in the relative importance of Norway lobster in 2003 found. The modifications to specific composition may be mainly due to changes in the behaviour of the fleet and so in target species, or to changes in the abundance of the species in the area where it is exploited. This fall in the abundance of the Norway lobster in 2003 was previously observed by Sánchez et al (2005) in the area of Galicia (ICES Sub-divisions VIIIc East and Ixa North), although this trend had been observed in the survey of the previous autumn (2002), before the Prestige accident. Moreover, it must be taken into account that the populations of the Cantabrian Sea and Galicia are considered to be outside safe biological limits since (ICES, 2004). Nevertheless, it should also be remembered that in the case of the Prestige, large quantities of oil have been found in the sediment (Punzon and Serrano, 2003, Sánchez et al, 2003), which is one of the explanations given for the high concentrations of PAHs in Norway lobster tissues in the accident of the Braer in the Shetland Islands (Crean and Lacambra, 2003). In addition, in this case and unlike what happened in fishes, in which the high concentrations of PAHs quickly diminished (Moller, et al., 1999), in the case of Norway lobster they remained high for a long time due to their being continually in contact with sediment contamination, although no harm has been detected to date (Moller et al., 1999), In this case the Norway lobster fishery was closed until March 2000 (Fisheries Research Service, 2000),. In the case of the Prestige accident, analysis of PAH content in Norway lobster tissues has not yet been performed, and so nothing is known of PAH levels nor their evolution.

In addition to what has already been considered, it must be taken into account that a large part of the fisheries in the area received subsidies of different kinds (Surís and Garza, 2003), and as in other spills (Born, et al., 2003) some of them participated in the cleaning-up work, receiving income according to trips made out to sea. This kind of subsidy can have diverse consequences, such as favouring the abandonment of the activity, changes in technical characteristics, fleet renewal, exploration for new fishing grounds and/or resources, etc. These aspects have yet to be analysed, and doing so requires a longer time scale.

There are several considerations for future accidents that can be derived from this study. In addition to carrying out an immediate analysis of the resources susceptible to damage by the spill, the fisheries that may be affected by closed areas must also be analysed, because the closing areas in an affected area is mandatory (Moller, et al. 1999). The analysis of the seasonality of fisheries and the management measures already in place should be assessed a priori, not only to observe any possible changes in catches or effort, but also to identify those that may qualify for subsidies, and formulate a sampling design to identify its consequences. This will also let us know which fisheries are going to be operative during the establishment of closed areas and carry out sampling in order to study the workability of gears, observe possible changes in effort and the way it is exerted and collect biological material. Lastly, the collection of diverse biological material, paying special attention to crustacea closely related to the sediment, in order not only to safeguard consumer health, but also to support later results, as in the case of Norway lobster in this study, for example.

6 Acknowledgements

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8 Figures

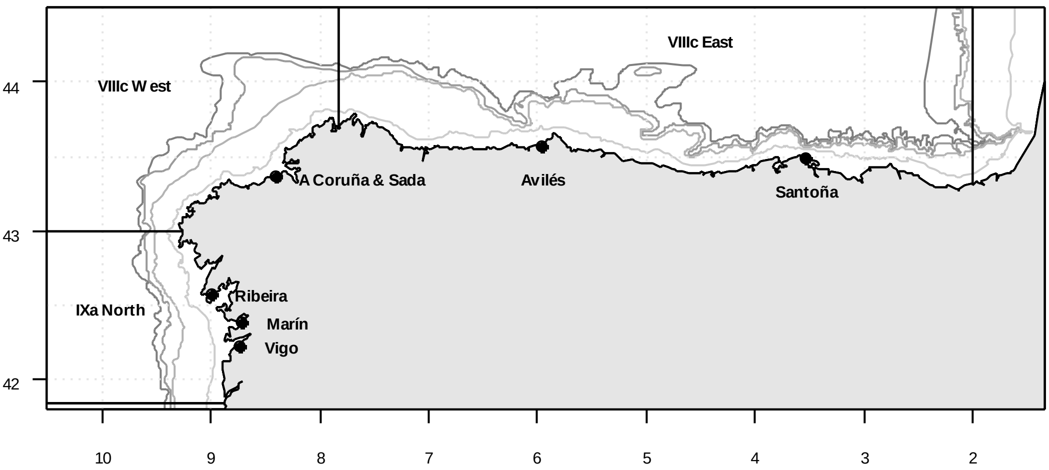


Figure 1. Study area and base ports of the fleets analysed

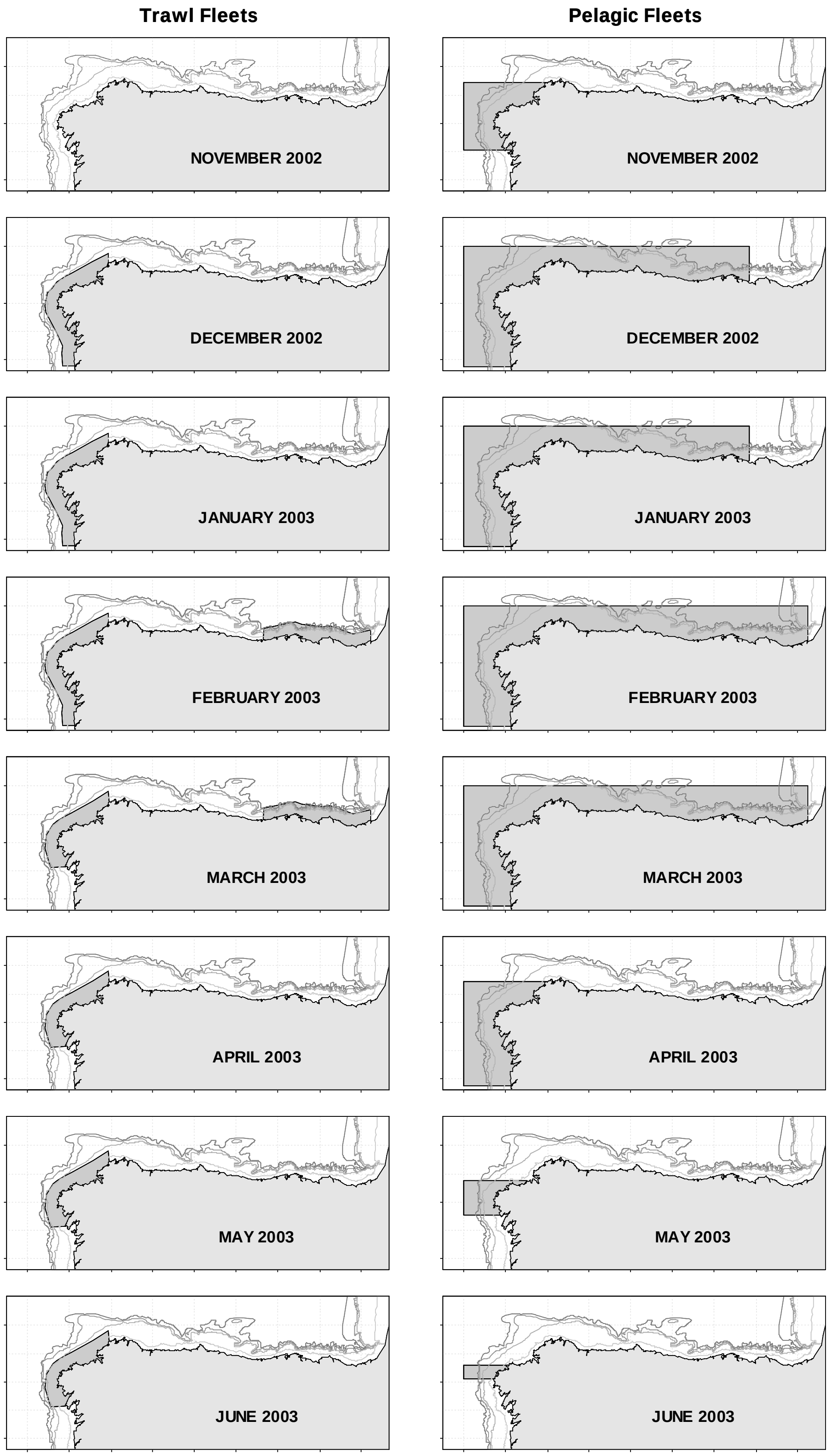


Figure 2. Maps of the location of seasons and closed areas (shaded area) imposed on trawl and pelagic fleets

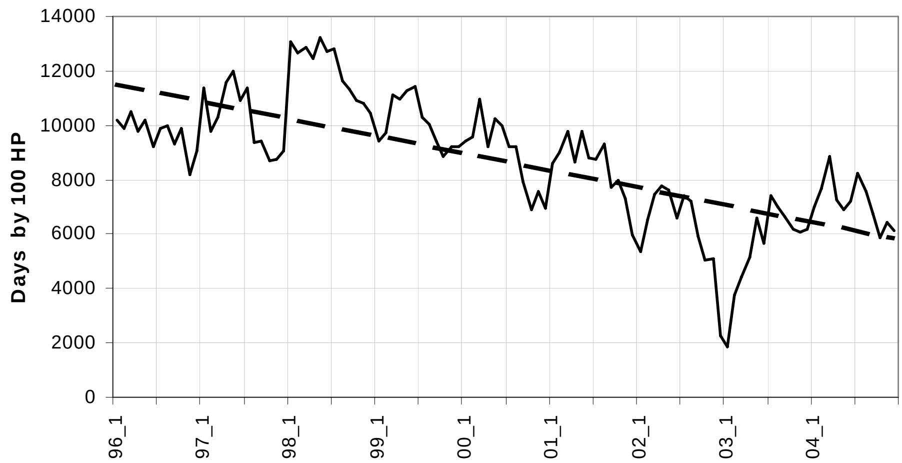


Figure 3. Total effort (days per 100 HP) of trawl fleets between 1996-2004 in ICES Division VIIIc and Sub-division IXa North and the trend line

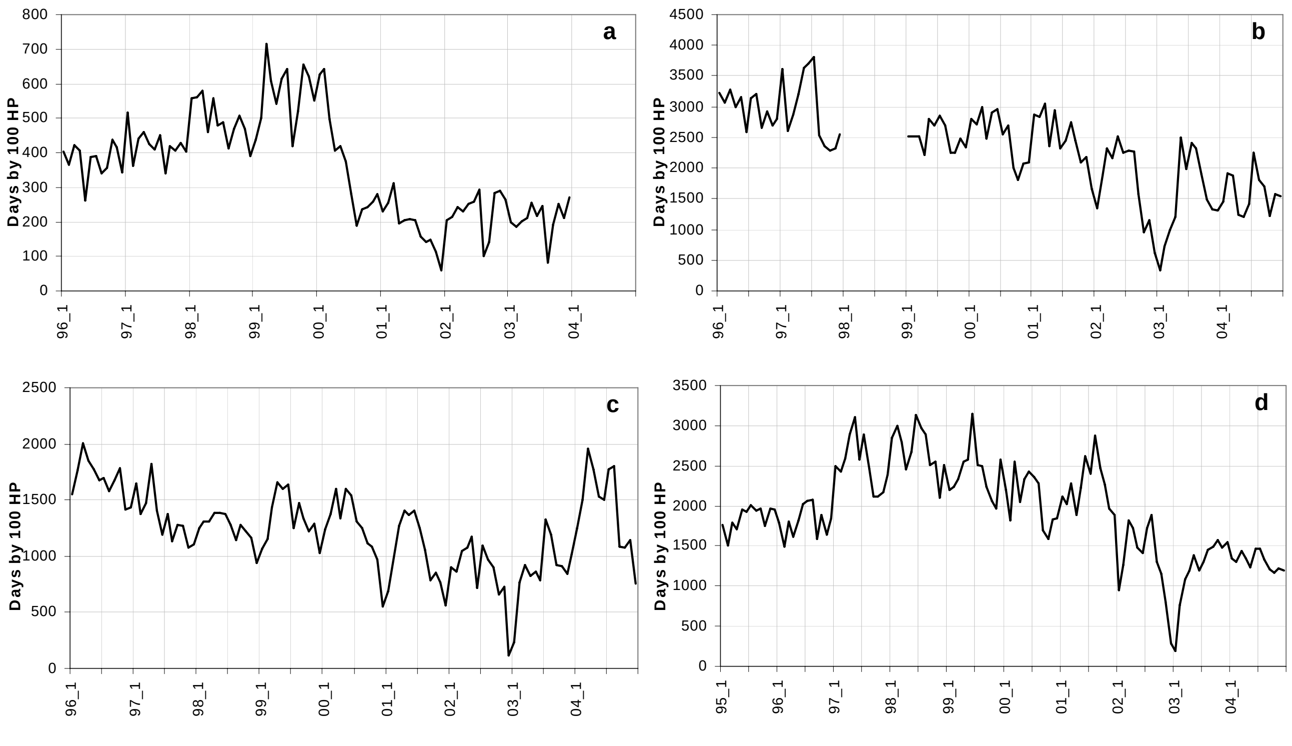


Figure 4. Baca trawl effort (Days per 100 HP) by fleets: (a) Avilés fleet, (b) A Coruña fleet, (c) Ribeira fleet and (d) Marín fleet

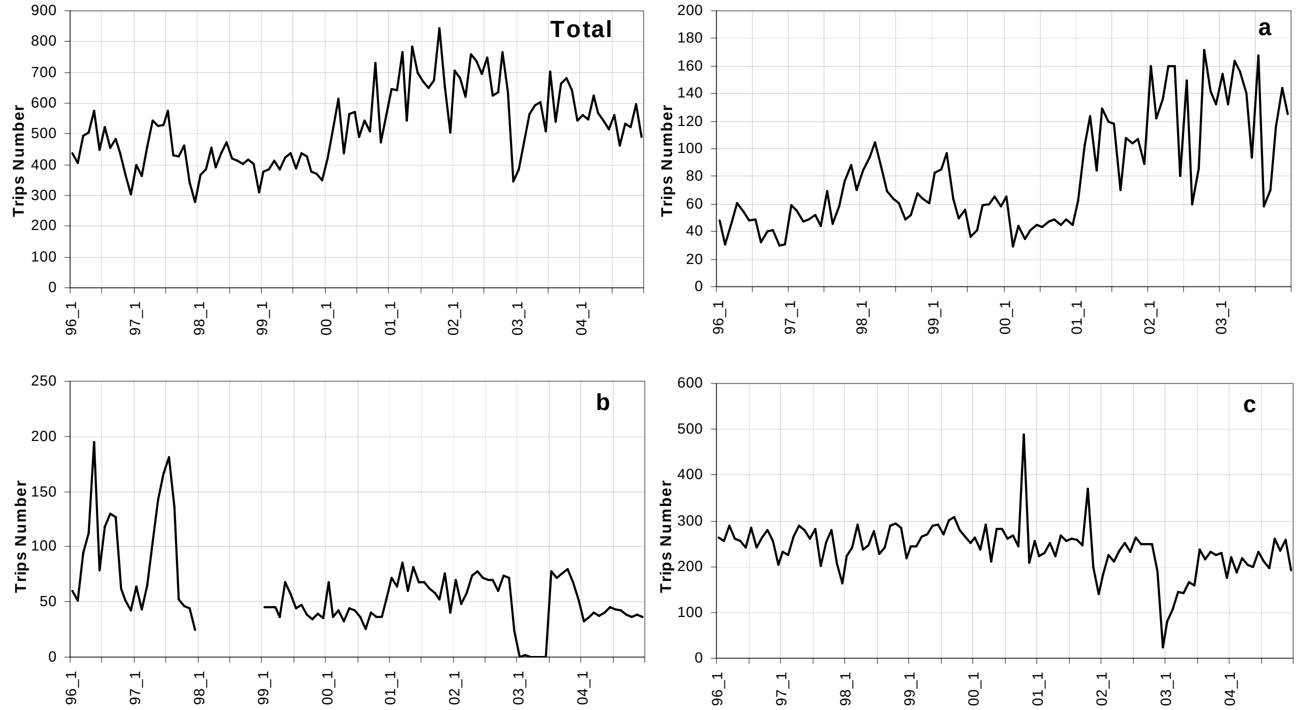


Figure 5. Pair trawl effort (number of trips) total and by fleets: (a) Avilés fleet (b) A Coruña fleet and (c) Ribeira fleet

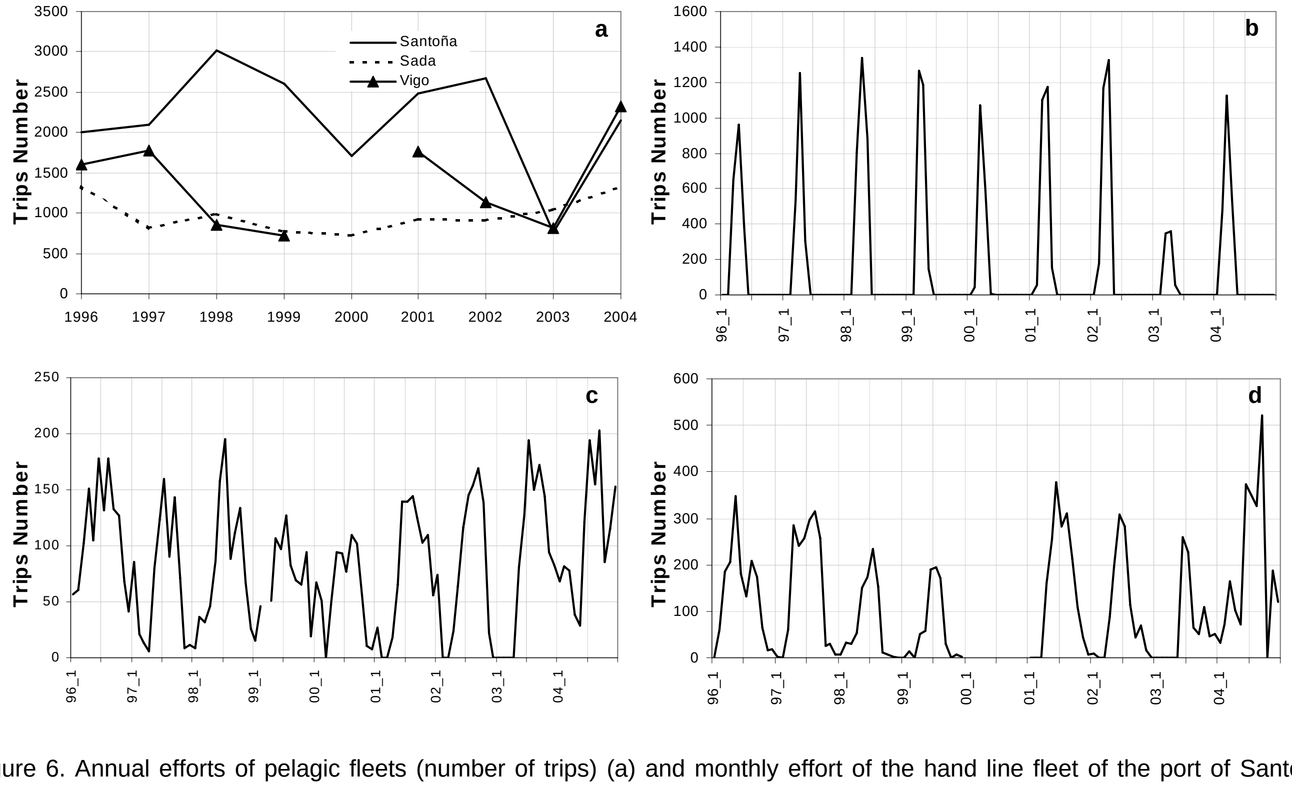
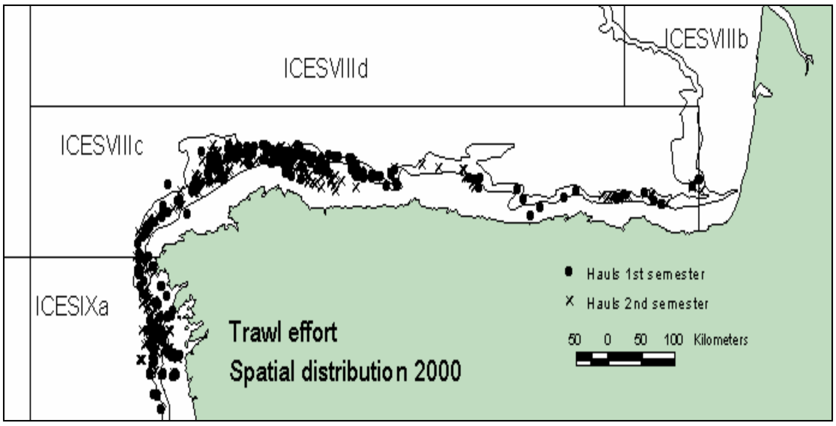


Figure 6. Annual efforts of pelagic fleets (number of trips) (a) and monthly effort of the hand line fleet of the port of Santoña targeting mackerel (b), and of the purse seine fleets of Sada (c) and Vigo (d) targeting sardine.



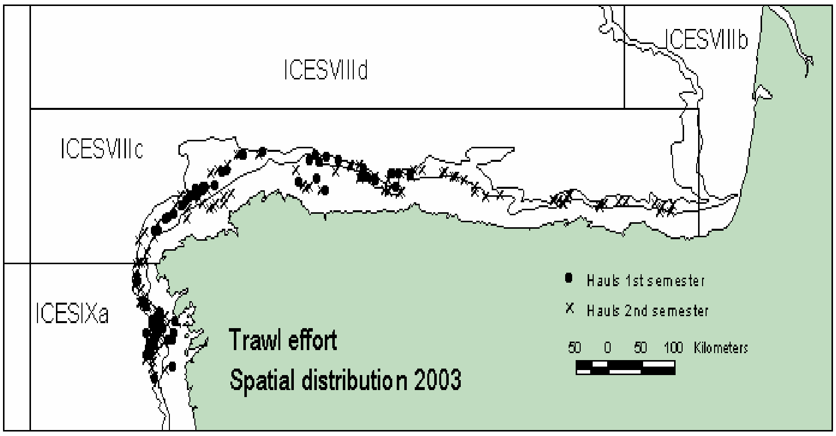


Figure 7. Spatial distribution of the sampled trawl fleet in ICES Sub-division IXa North and Division VIIIc by years

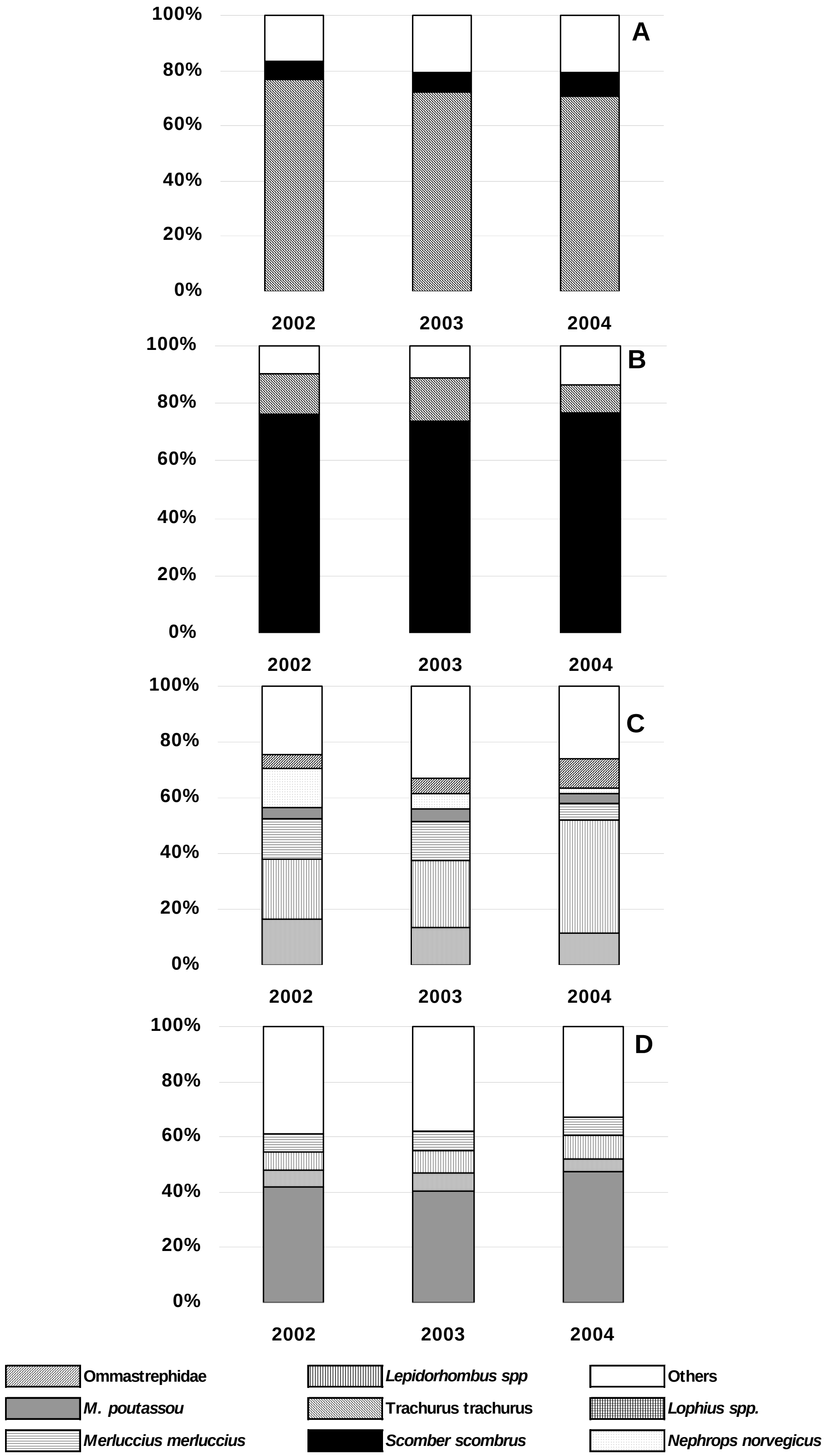


Figure 8. Interannual changes (2002-2004) in the target species of the different trawl components: (a) horse mackerel component (b) mackerel component (c) HMMN component and (d) blue whiting component

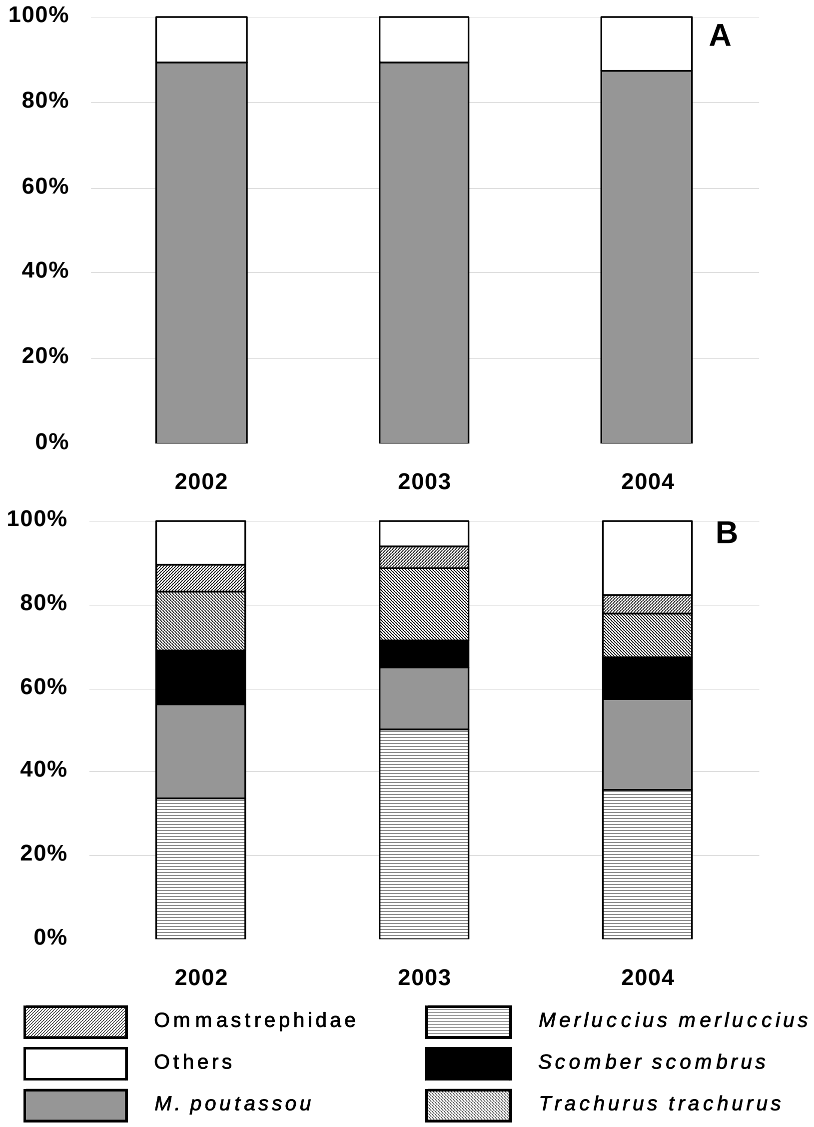


Figure 9. Interanual changes (2002-2004) in the target species of the different pair trawl components (percentage): a) Blue whiting component and b) hake component

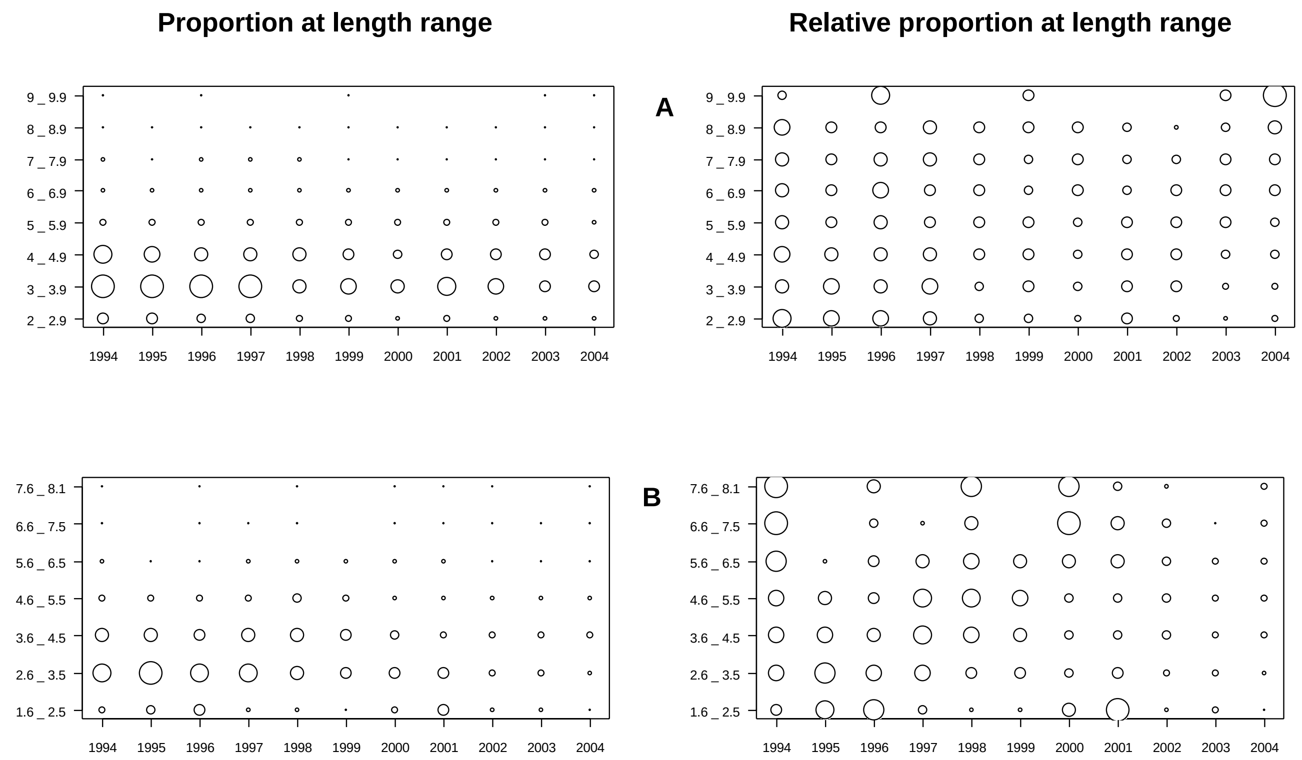


Figure 10. Exploitation strategy for Norway lobster of the baca trawl fleet: (a) ICES Divisions VIIIc and (b) ICES Sub-division IXa North

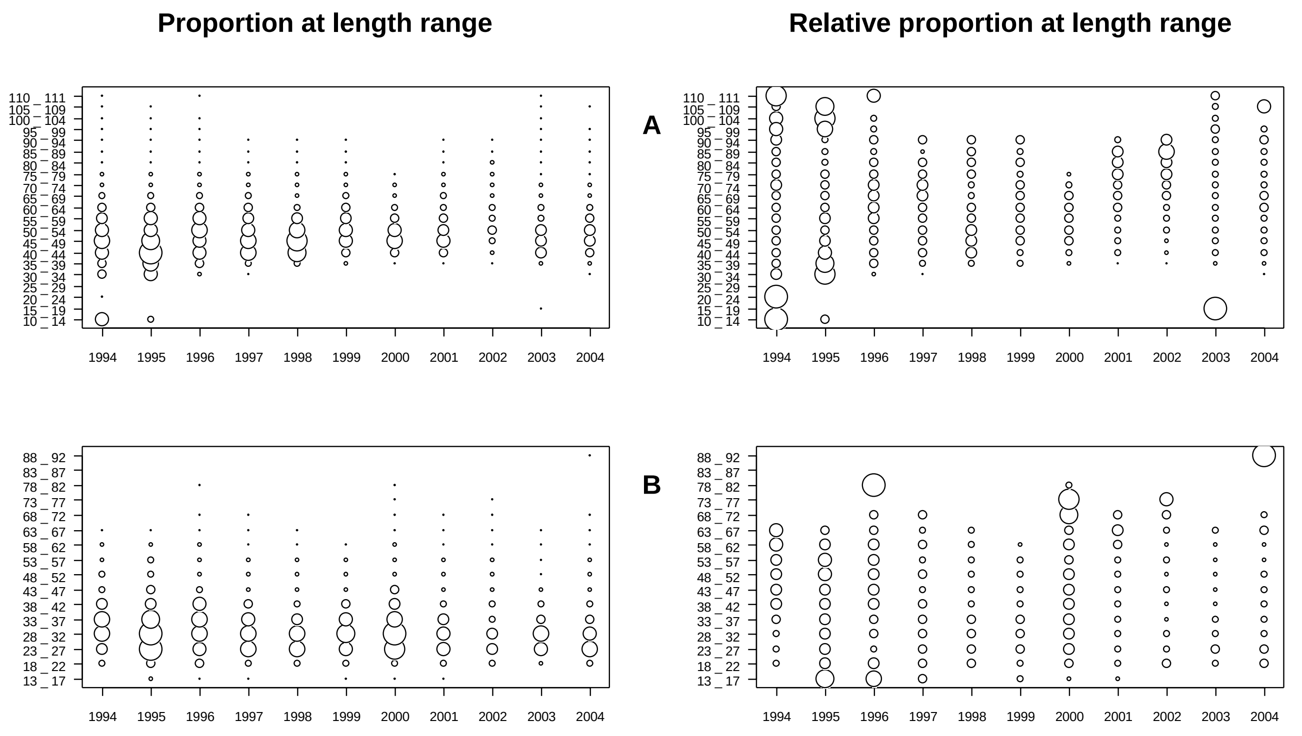


Figure 11. Exploitation strategy for hake of the trawl fleet : (a) ICES Divisions VIIIc and (b) ICES Sub-division IXa North

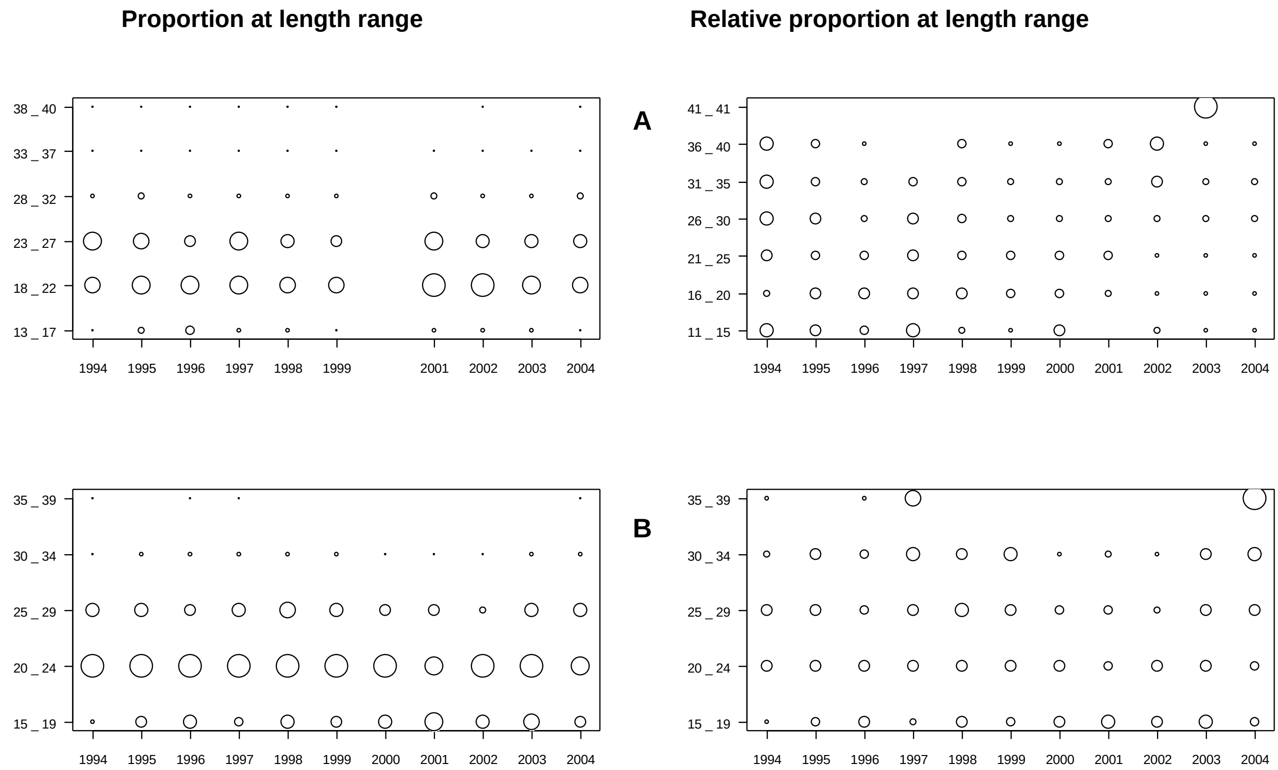


Figure 12. Exploitation strategy for blue whiting of the pair trawl fleet: : (a) ICES Divisions VIIIc and (b) ICES Sub-division IXa North

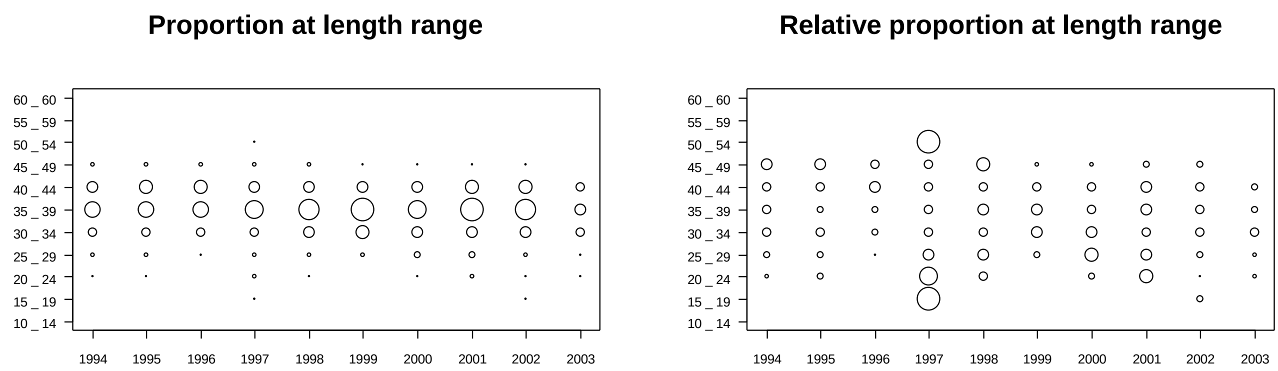


Figure 13. Exploitation strategy for mackerel of the hand line fleet in ICES Sub-division VIIIc East

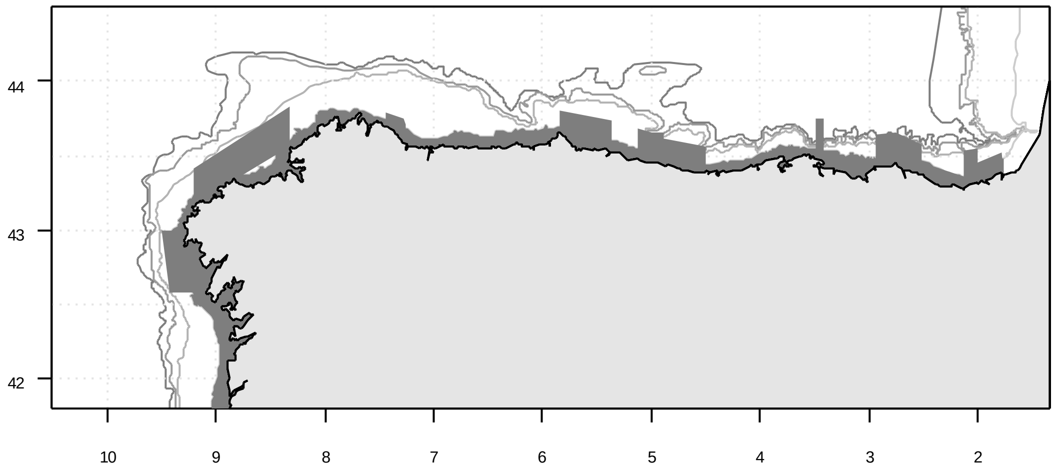


Figura 14. Spatial closures imposed on trawl annually

9 <u>Tables</u>

Table 1. Fleets used for the analysis of effort

Fleet	Port	ICES Area	Gear	Target Species
Demersal	Avilés	Sub-division VIIIc East	Bottom Trawl Pair Trawl	Mixed
	A Coruña	Sub-division VIIIc West	Bottom Trawl Pair Trawl	
	St. Eugenia de Ribeira	Sub-division IXa North	Bottom Trawl Pair Trawl	
	Marín	Sub-division IXa North	Bottom Trawl	
Pelagic	Santoña	Sub-division VIIIc East	Hand Line	Mackerel
	Sada	Sub-division VIIIc West	Purse Seine	Sardine
	Vigo	Sub-division IXa North	Purse Seine	Sardine

Table 2. Total annual effort exerted by the bottom trawl and pair trawl fleets in ICES Sub-divisions VIIIc East and West and IXa North.

	Fleet	
Year	**Bottom Trawl (Days per 100 HP)**	**Pair Trawl (Trips Number)**
1996	116127	5440
1997	122593	5343
1998	107228	4074
1999	120899	4764
2000	107192	6426
2001	101703	5312
2002	74351	7954
2003	66902	6906
2004	85912	6529

Table 3. Exploitation strategies analysed

	Trawl	Pair Trawl	Hook	Gillnet
Hake	**X**	**X**	**X**	**X**
White Anglerfish	**X**			**X**
Black Anglerfish	**X**			**X**
Megrim	**X**			
Four Spot Megrim	**X**			
Nephrops	**X**			
Blue Whiting	**X**	**X**		
Mackerel			**X**	
Horse Mackerel	**X**			